African Journal of Agricultural Research Vol. 5(12), pp. 1482-1496, 18 June 2010
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJPP10.126
ISSN 1991-637X ©2010 Academic Journals

Full Length Research Paper

Parametric approach to land evaluation for forest plantation: A methodological study using GIS model

Orhan Dengiz[1], Ceyhun Gol[2]*, Fatma Esra Sarioğlu[1] and Semih Ediş[1]

[1]Department of Soil Science, Agricultural Faculty, Ondokuz Mayis University, Samsung -Turkey.
[2]Department of Watershed Management, Faculty of Forestry, University of Çankırı Karatekin 18200, Çankiri, Turkey.

Accepted 12 May, 2010

In this study, the land suitability analysis has been carried out to identify suitable areas found in the Yeşilirmak Delta and the Central Black Sea Region of Turkey for afforest plantation. Climate, slope, soil, topography and vegetation were considered as important factors in identifying suitability. Climate and topography were considered as homogenous throughout the study area. The required soil data were obtained from detailed soil map sheet of 1:25.000 scales. The spatial layers were analyzed and incorporated into the geographical information system (GIS) environment. Criteria for land suitability of each land use types; *Pinus pinaster* Ait., *Pinus radiata* D. Don, *Pinus pinea* L., *Populus* L. *Salix alba* L., *Robinia pseudoacacia* L., *Fraxinus excelsior* L., *Juglans regia* L. have been identified from many literatures and studies. Each soil characteristic with associated attribute data is digitally encoded in a GIS database to eventually generate eight thematic layers. The diagnostic factors of each thematic layer were assigned values of factor rating. Finally, suitability maps for each land unit type were prepared with three suitability categories namely, suitable, moderately suitable and not suitable. According to the final suitability maps of the species, highly suitable category of the study area for *P. pinaster*, .*P. radiata*, *P. pinea*, *Populus, S. alba*, *R. pseudoacacia*, *F. excelsior*, *J. regia* are 15.7, 15.2, 38.8, 65.9, 64.7, 50.1, 56.1 and 63.3%, respectively.

Key words: Parametric approach, forest land evaluation, land characteristics, GIS modeling.

INTRODUCTION

Land evaluation is the process of predicting land performance over time according to specific types of use (Diepen et al., 1991; Rossiter, 1996). The basic problem constrains the productive capacity of land resource (UN, 1986). It comprises a range of methods developed to enable the assessment of land in terms of either capability for general land uses. The concepts and principles of land evaluation as well as the various definitions associated with land evaluation are presented in the Food and Agriculture Organization (FAO, 1976) publication, "A Framework for Land Evaluation". In addition, the FAO organized workshops leading to publication of guidelines for land evaluation in dry land agriculture (FAO, 1983), irrigated agriculture (FAO, 1985), forestry (FAO, 1984), extensive grazing (FAO, 1981), steep lands (Millington, 1984).

Land evaluation has traditionally been based primarily on soil surveys. If the land use requirements are known, they can be matched with the group of land characteristics or the land quality (Ikawa, 1992). Therefore, soil characterization and soil classification by using soil map serve as efficient tools in land evaluation. McBratney et al. (2000) also stated that soil survey may be thought of as base data involving field description and laboratory analysis and subsequent classification and mapping of the study area for land evaluation. They also stated that effective soil management requires an understanding of soil distribution patterns within the landscape and also that soil survey mapping is the most enable data for wise decision regarding land use and land evaluation by planners and policy maker.

Dayawansa and Ekanayake (2003) investigated to identify suitable areas within the University of Peradeniya, Sri Lanka for a production forest using GIS. In their study, climate, slope, soil, topography, and

*Corresponding author. E-mail: ceyhungol@karatekin.edu.tr. Tel: +90 376 2133582. Fax : +90 376 2124322.

vegetation accessibility were considered as important factors in identifying the suitability. According to the final suitability map, they have found that 5.35 ha of land are under highly suitable category and 0.65 ha of land are under moderately suitable category. The majority of the land (68.5 ha) is not suitable according to the given criteria.

Yüksel et al. (2001) determined relationships of suitability between land use types and soils in the Kenbag Nursery (Cankiri). After describing land requirements for each shoot, grown in the study area and examination of land characteristics from detailed soil map, the most suitable fields were determined and mapped for each land use type. Today, people are becoming more environmentally aware, resulting in greater priority for adopting sustainable use of natural resources in the World. The main aim of this research was to define suitable areas for forest plantation in terms of ecological, economical and social using parametric approach system. The system is an interpretation and calculation of rate of parameters derived from several sources. It is based on an assessment of increasing degree of limitation imposed by the physical factors collected from fieldwork and documents data on the growth of trees and silivicultural practices.

MATERIALS AND METHODS

Field description

The study was conducted in the Çarşamba Plain found in the Yeşilırmak Delta and located in the central Black Sea Region of Turkey (Figure 1). The study area (around the Dikbıyık District) is far about 10 km from north of the Samsun -Çarşamba country and coordinated 45669281 - 4582885 N - S and 291727 -302306 E-W (UTM). The study area covers about 6080 ha and it lies at an elevation from sea level of 1-2 m. The current climate in the region is semi-humid. The summers are warmer than winters (the average temperature in July is 23.5 and in January is 6.2°C). The mean annual temperature, rainfall and evaporation are 14.3ºC, 1045.2 and 739.1 mm, respectively. According to Soil Taxonomy (1999), the study site has mesic soil temperature regime and ustic moisture regime. These areas are mainly flat and slightly sloped (0.0-1.0%). Total 8 soil series were described in the study area. The majority of soils were classified as vertisol (25.2%), inceptisol (33.4%), alfisol (12.8%) and entisol (19.6%) orders in Soil Taxonomy (1999). Surface soil texture is generally heavy (31-65% clay), while sub soil texture is different due to alluvial deposit in the study area. Soil organic matter content ranges from 0.90 to 4.12%. Soil reaction (pH) and electrical conductivity (EC) values of soils are changing between 7.80 - 8.22 and 0.24 -1.49 dS m^{-1}. However, EC'values strongly increase closing to coast land because of water effect of sea. Intensive agricultural activities have been conducted in the study area. Rice, maize, pepper, watermelon, cucumber and tomato with sprinkler and furrow irrigations have been produced in the summer, and cabbage and leek in winter. In addition, some part of the study area is covered with forest, pasture-meadow, marsh and dune areas

METHOD

The methodology used is based on the FAO approach for land evaluation for forestry (FAO, 1984). In addition, the parametric evaluation system developed by Riquier et al. (1970) was firstly applied during data processing in this study.
The main stages are as follows:

1. Selection of the species: This selection is made according to the economic, social, and ecological properties of the study area. It is found out that people mostly value tree to provide food security, to generate some income, to protect cultivated area and to fix the dunes. According to these criteria and the floristic list carried out from the fieldwork, eight tree species were chosen: *P. pinaster, P. radiata, P. pinea, Populus, S. alba, R. pseudoacacia, F. excelsior,* and *J. regia.*
2. Determination of ecological parameters that enables the understanding of the behavior of species regarding edaphic and environmental conditions: climatic data such as elevation range, mean annual temperature, and mean annual rainfall are almost constant. Besides, geomorphology especially slope is also almost flat in the study area. So they had not been taken into account because of the homogeneity of the study area from this point of view. The parameters chosen are related to the soil properties such as drainage, depth, pH and so on.
3. Determination of classes for each ecological parameter: the behavior of the tree species was examined regarding the ecological parameters of the Black Sea Region condition. Growth land requirements of all the tree species were reviewed from many literatures and studies (Parker et al., 1992; Olarieta et al., 2006; Sarıbaş, 2008; Ürgenç, 1972; Şimşek, 1982; Tunçtaner et al., 1985; Sever and Makineci, 2008; Toplu et al., 2002; Anşin and Özkan, 1997; Anonymous, 1994; Kantarci, 2005; Yaltırık and Efe, 2000; Rietveld, 1982; Todhunter and Beineeke, 1984; Saatçioğlu, 1976; Pinto, 2004; Pini et al., 1999; Redei et al., 2008).

Data collection

Soil data such as drainage, pH, EC, depth, texture, organic carbon, calcium carbonate, and coarse fragment were taken from digital soil map scaled 1:25.000 and soil data base of the study area. Thus, soil information on each diagnostic characteristic of soil chemical and soil physical properties was obtained from land mapping units (LMUs) of soil map. A total of 29 different polygons or LMUs was determined in the base map and was also given soil characteristics for each LMUs. These values were used to generate a land suitability map for all species using GIS.

Data processing

Each class of every ecological parameter was classified with a determined value for each species. The value ranges from zero (worst conditions) to one hundred (optimum conditions). This was done to show the behavior of the species regarding the chosen parameters as shown in Tables 2, 3, 4, 5, 6, 7, 8 and 9. To evaluate the land suitability for forest plantation method, the parametric evaluation system of FAO (1983 and 1984) and parametric model were applied using the soil characteristics. These characteristics of each LMUs are rated and used to calculate the final index for suitability classes of each species.
According to the formula [1]

$$FI = R_{max} \sqrt{A \times B \times C \times \ldots\ldots} \quad [1]$$

Where,

FI= Final Index,

R_{max}= Average maximum rate and,

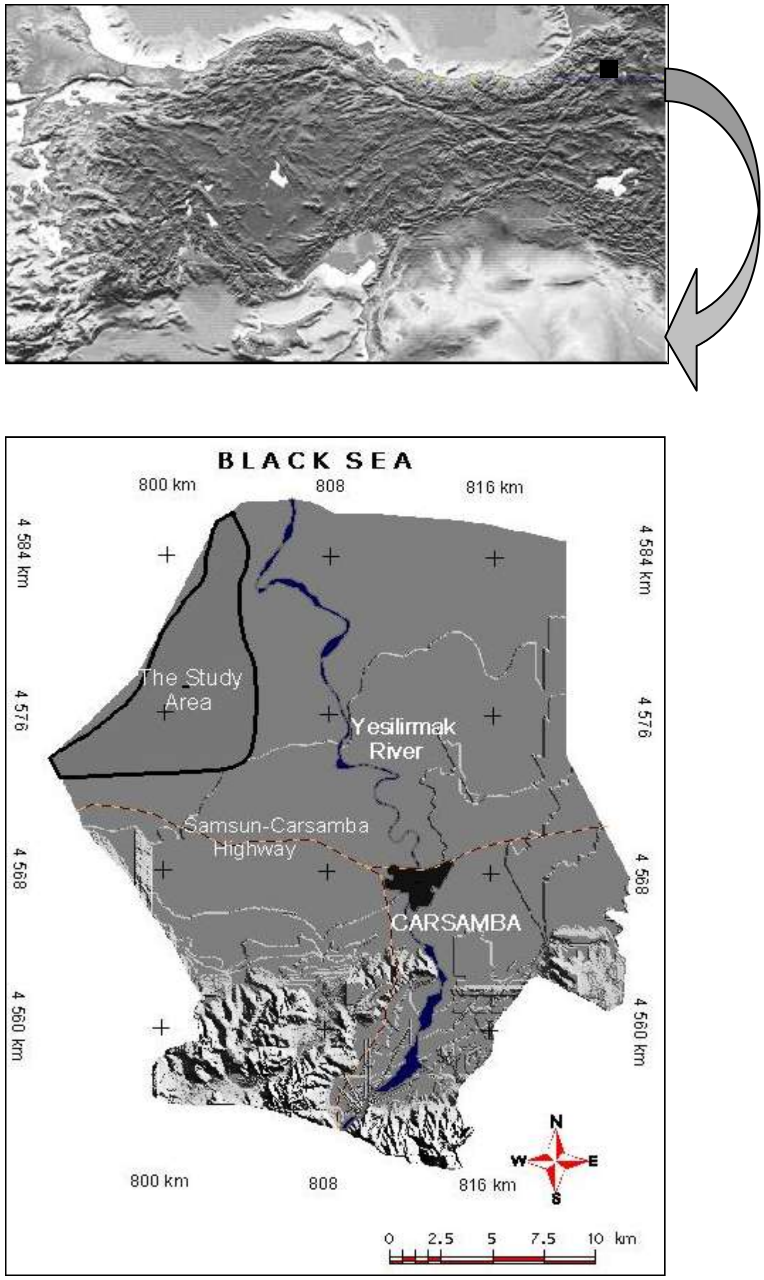

Figure 1. Location map of the study area.

A, B, C…= Soil characteristics

The soil characteristics used for this evaluation include two main properties; i-soil physical factors which include drainage (A), soil depth (B), texture (C), and coarse fragment (D); ii- soil chemical factors which consist of organic matter (E), soil reaction (F), salinity or electrical conductivity (G), and calcium carbonate (H). Suitability classes are defined by considering the final index and are presented in Table 1.

Each soil characteristic with associated attribute data is digitally encoded in a GIS database to eventually generate eight thematic layers. The diagnostic factors of each thematic layer were assigned values of factor rating identified in Tables 2, 3, 4, 5, 6, 7, 8, and 9. The parametric model is defined using the value of factor rating as formula [1]. These eight layers were then spatially overlaid to produce resultant layers for each species. Schematic chart of the spatial overlay showing the soil characteristics is illustrated in Figure 2. All these data were analyzed using TNT Mips 6.4v MicroImage GIS and Remote Sensing (RS) program.

RESULTS AND DISCUSSION

The study area is under strong human and environmental pressure due to social, economic, dune coastal activities. Many villages are located near the managed forest or natural formations in the study area. Therefore, the wood

Table 1. Final index and definition of the suitability classes.

Final index	Definition	Symbol
>80	Highly suitable	S1
60-80	Moderately suitable	S2
30-60	Marginally suitable	S3
<30	Non suitable	N

Table 2. Factor rating of land characteristics and suitability class for *Pinus pinaster* Ait.

LMU	Soil physical and chemical characteristics								Final index	Class
	Drainage	Depth	pH	EC	$CaCO_3$	O.M	Texture	C.F		
Cs.1	100	80	10	100	100	100	100	100	87	S1
Cs.2	80	80	80	100	100	100	100	100	66	S2
Cs.3	100	100	100	100	100	100	100	100	100	S1
Ay.1	50	100	80	100	100	100	50	100	38	S3
Ay.2	30	100	80	100	30	100	30	100	10	N
Ka.1	80	100	80	100	80	100	100	100	66	S2
Ka.2	100	100	80	90	100	100	100	100	82	S1
Cy.1	30	100	80	100	80	100	30	100	19	N
Cy.2	30	100	80	100	80	100	50	100	25	N
Cy.3	80	100	80	100	80	100	30	80	28	N
Ki.1	80	100	100	100	80	100	50	100	50	S3
Ki.2	100	80	100	80	100	100	100	100	76	S2
Ki.3	80	100	100	100	100	100	100	100	87	S1
Ki.4	50	100	80	100	80	100	50	100	33	S3
Ki.5	100	100	100	100	100	100	100	100	100	S1
Ac.1	30	100	100	100	80	100	30	100	21	N
Ac.2	80	100	100	100	100	100	80	100	76	S2
Ac.3	30	100	100	100	80	100	80	100	38	S3
Ac.4	30	100	100	100	80	100	30	100	21	N
Ep.1	50	100	80	100	80	100	70	100	40	S3
Ep.2	30	100	50	100	100	100	40	100	19	N
Ep.3	50	100	80	100	100	100	30	100	29	N
Kt.1	50	100	100	100	100	100	30	100	33	S3
Kt.2	100	100	80	90	100	100	100	100	82	S1
Kt.3	80	100	100	100	100	100	80	100	76	S2
Kt.4	100	100	100	100	100	100	100	100	100	S1
Kt.5	100	100	100	100	100	100	100	100	100	S1
Kt.6	50	100	100	100	100	100	50	100	44	S3
Kt.7	100	100	100	100	100	100	100	100	100	S1

LMU: Land Mapping Unit, CF: Coarse Fragments, OM: Organic Matter, EC: Electrical Conductivity.

Table 3. Factor rating of land characteristics and suitability class for *Pinus radiata* D. Don.

L.M.U	Soil physical and chemical characteristics								Final index	Class
	Drainage	Depth	pH	EC	$CaCO_3$	O.M	Texture	C.F		
Cs.1	100	80	100	100	100	100	80	100	76	S2
Cs.2	80	100	80	100	100	100	80	100	66	S2
Cs.3	100	100	100	100	100	100	100	100	100	S1
Ay.1	30	80	100	100	80	100	30	100	19	N
Ay.2	80	100	100	100	100	100	80	100	76	S2
Ka.1	50	100	100	100	80	100	80	80	44	S3
Ka.2	80	100	100	100	100	80	80	80	58	S3
Cy.1	50	100	100	100	100	80	80	100	50	S3
Cy.2	30	100	100	100	100	80	60	100	32	S3
Cy.3	80	100	100	100	100	80	80	100	66	S2
Ki.1	80	100	100	100	80	100	100	100	76	S2
Ki.2	100	80	100	100	100	100	100	100	87	S1
Ki.3	100	100	100	100	100	100	100	100	100	S1
Ki.4	50	100	100	100	80	100	60	100	42	S3
Ki.5	100	60	100	100	100	100	100	100	74	S2
Ac.1	30	100	80	100	80	100	80	80	28	N
Ac.2	80	100	80	100	100	100	100	100	76	S2
Ac.3	60	100	80	100	100	100	100	100	64	S2
Ac.4	40	100	80	100	80	100	60	100	32	S3
Ep.1	50	100	100	100	100	100	100	100	66	S2
Ep.2	30	60	100	100	100	100	40	100	21	N
Ep.3	50	100	100	100	100	100	60	100	49	S3
Kt.1	80	80	100	100	100	100	80	90	62	S2
Kt.2	100	100	100	100	100	100	100	90	94	S1
Kt.3	60	100	100	100	80	100	60	100	47	S3
Kt.4	100	100	100	100	100	100	100	100	100	S1
Kt.5	100	100	100	100	100	100	100	100	100	S1
Kt.6	100	100	100	100	100	100	100	100	100	S1
Kt.7	100	100	100	100	100	100	100	100	100	S1

LMU: Land Mapping Unit, CF: Coarse Fragments, OM: Organic Matter, EC: Electrical Conductivity

collection and agricultural practices are intense and the grazing compromises the natural regeneration of the tree species. Suitability for forest plantation is considered as tree species for economic and social purposes (paper wood, fuel wood, timber, pulpwood, grazing and so on) and for naturalistic conservation purposes to combat land degradation such as severe wind exposure and coastal dune activity in the study area. Kilic et al. (2005) quantified biophysical and economical potential of the Amik Plain which is one of the nation's most productive prime farmlands under great pressures due to the sprawls of urban and industrial areas. Researchers also determined the basis for proposing a range of sustainable land use land cover options for the region. Some researchers (Evrendilek and Doygun, 2000) emphasized that land use decisions made by local administrations be compatible with sustainable use and management principles of natural resources.

Two land use types (*P. pinaster* and *P. radiata*) were considered for environmental forestry to conserve soil in coastal dunes. Especially, *P. pinaster* due to the results of fast growing species, the land is quickly covered with vegetation. In this case, these species are highly and moderately suitable as windbreaks in the area close to beach to prevent sand movement. Thus, the fertile agricultural areas can also be protected from negative effects of wind erosion. *P. pinaster* has characteristic of a pioneer species. It registers higher growth rates in low and medium altitudes (between sea level and 1100 m) in site with 11 - 15°C as an average annual temperature (Tunçtaner et al., 1985; Pinto et al., 2004). It is a very tolerant species with preference light and sandy texture, low organic matter content or non fertile soil and growing very well on soil reaction between 5.0 - 6.5 pH. These soil properties are to be found commonly in Costal, Karabahcekoy and Kumtepe soil series. 31.3% of the

Table 4. Factor rating of land characteristics and suitability class for *Pinus pinea* L.

L. M. U	Soil physical and chemical characteristics								Final index	Class
	Drainage	Depth	pH	EC	$CaCO_3$	O. M	Texture	C.F		
Cs.1	60	60	100	100	100	80	30	40	13	N
Cs.2	100	80	100	100	100	100	60	60	47	S3
Cs.3	30	50	100	100	100	60	30	30	6	N
Ay.1	80	100	100	100	100	100	80	100	76	S2
Ay.2	100	100	100	100	100	100	100	100	100	S1
Ka.1	80	100	100	100	100	100	100	100	87	S1
Ka.2	100	100	100	60	100	100	100	100	74	S2
Cy.1	60	100	80	100	80	100	60	100	41	S3
Cy.2	70	100	100	100	100	100	80	100	70	S2
Cy.3	80	100	100	100	100	100	80	100	76	S2
Ki.1	80	100	80	100	100	80	80	100	58	S3
Ki.2	30	60	80	30	100	60	80	100	10	N
Ki.3	50	100	100	80	100	80	50	100	33	S3
Ki.4	30	60	80	10	100	100	10	100	2	N
Ki.5	10	50	80	10	100	50	30	80	1	N
Ac.1	100	100	100	100	100	100	80	100	87	S1
Ac.2	100	100	100	70	100	100	100	100	81	S1
Ac.3	100	100	100	100	100	100	100	100	100	S1
Ac.4	100	100	100	100	100	100	100	100	100	S1
Ep.1	90	100	100	100	100	100	90	100	88	S1
Ep.2	80	100	100	100	100	100	70	100	70	S2
Ep.3	80	100	100	100	100	100	100	100	87	S1
Kt.1	100	100	100	100	100	100	100	100	100	S1
Kt.2	50	60	100	50	100	100	30	100	16	N
Kt.3	50	100	100	70	100	100	50	100	35	S3
Kt.4	10	60	100	10	100	0,80	100	100	5	N
Kt.5	30	80	100	80	100	100	40	40	12	N
Kt.6	100	100	100	70	100	100	100	100	81	S1
Kt.7	10	60	100	10	100	80	100	100	5	N

LMU: Land Mapping Unit, CF: Coarse Fragments, OM: Organic Matter, EC: Electrical conductivity.

study area was determined highly and moderately suitable species for the *P. pinaster* Ait., whereas rest of the total area is marginally suitable or non suitable due to mainly poor soil drainage. In addition, these species are also non suitable in lagoonal, marsh-swamp areas (Figure 3).

P. radiata is one of the most widely used species for intensive plantation forestry (Olarieta et al., 2008). Knowledge about land and soil characteristics influences the performance of *P. radiate*. Many researchers indicated in their reports that soil rootable depth is an important factor and they suggested that it should be more than 50 or 60 cm (Turvey et al., 1986; Romanya and Vallejo, 2004; Sarıbas, 2008). In addition, this species requires well aeration and well-drained soils. Optimum pH value for growth of *P. Radiata* is similar to requirement of *P. pinaster.* 15.2% of the study area was classified as highly suitable, covering mainly Kirenlik, Kumtepe and some parts of the costal soil series; about half or the total area (46.1%) is marginal or non suitable land for that species due to poor soil drainage, heavy soil texture and very shallow soil depth (Figure 3).

This result arises from the particular ecology of these species, which adapts quite well even to difficult environmental conditions and soils. As for wood production, *P. pinea*, *F. excelsior* and *J. regia* species were selected. Commercial or production forestry is directed at supplying national or export market. Commercial forest plantations can be subdivided into intended use for timber or for pulpwood (FAO, 1984). Fast-growing drought resistant *P. pinea* is a natural fuel wood candidate.

This wood, because of its high heat content, burns slowly. It is highly suitable in the Black Sea ecological conditions and should be an important source for generating incomes for the farmers in terms of its seeds, timber, and resin. In addition, these species are able to

Table 5. Factor rating of land characteristics and suitability class for *Populus* L.

L.M.U	Soil physical and chemical characteristics								Final index	Class
	Drainage	Depth	pH	EC	$CaCO_3$	O.M	Texture	C.F		
Cs.1	100	100	100	100	100	100	100	100	100	S1
Cs.2	100	100	100	100	100	100	100	100	100	S1
Cs.3	50	100	100	100	100	100	50	100	44	S3
Ay.1	100	100	100	100	70	100	100	100	81	S1
Ay.2	100	100	100	100	100	100	100	100	100	S1
Ka.1	100	100	100	100	100	100	100	100	100	S1
Ka.2	90	100	100	50	80	100	100	90	51	S3
Cy.1	70	100	100	100	100	100	100	80	70	S2
Cy.2	100	100	100	100	100	100	100	100	100	S1
Cy.3	100	100	100	100	100	100	80	100	87	S1
Ki.1	80	100	100	100	100	100	70	80	61	S2
Ki.2	10	100	80	10	50	100	100	100	4	N
Ki.3	100	100	100	30	50	100	100	100	33	S3
Ki.4	30	100	100	30	50	100	50	100	11	N
Ki.5	10	100	100	10	50	60	70	100	3	N
Ac.1	90	100	100	100	80	100	100	100	82	S2
Ac.2	100	100	100	100	80	80	100	100	76	S2
Ac.3	100	100	100	100	80	90	100	100	82	S1
Ac.4	100	100	100	100	80	100	100	100	87	S1
Ep.1	100	100	100	100	100	100	100	100	100	S1
Ep.2	100	100	100	100	100	100	100	100	100	S1
Ep.3	100	100	100	100	100	100	100	100	100	S1
Kt.1	80	100	100	100	100	100	100	90	82	S1
Kt.2	100	100	100	80	100	100	100	100	87	S1
Kt.3	90	100	100	80	100	100	100	90	76	S2
Kt.4	30	100	50	10	100	100	50	100	6	N
Kt.5	50	100	50	10	100	100	50	100	8	N
Kt.6	100	100	100	100	100	100	100	100	100	S1
Kt.7	80	100	100	50	100	100	70	100	46	S3

LMU: Land Mapping Unit, CF: Coarse Fragments, OM: Organic Matter, EC: Electrical Conductivity.

to build stable ecosystems on degraded land (Pinto et al., 2004). Therefore, it has ecological, social and economic value. It appreciates deep and light soils, which allow its tap root to develop and which are able to supply this tree with water. *P. pinea* develops on almost all types of substrates, calcareous or siliceous, and seems to be pH indifferent (5.5 - 8) (Pinto et al., 2004). This tree is almost suitable in 65% of the study area located generally in Agcasaz and some parts of the Ayazma and Epçeli soil series (Figure 4). It is marginally suitable in 10% of the land. *F. excelsior* is known as tree species with a rapid growth in the first decade after establishment and is expected to produce high value timber in relatively short rotation periods (Blaschke et al., 2008). *F. excelsior* has been found in small part of the study area soil (4%), classified as non suitable and along the dunes (mostly the part which is in front of the beach). Marsh-swamp areas are not suitable for this tree. It prefers soils often rich in clay or silt texture, deep and growing well on soils with pH between 4.5 and 7.5. It also has high tolerance in relation to the supply of water and nutrients. Almost all land mapping units are suitable for this species in the study area except for Cs.3, Ki.5 and Kt.7 LMUs (Figure 3).

J. regia has been considered to be more economically important because it is mostly appreciated as timber wood used for making tools. Besides, its fruit also has economical values for farmer's income. The best *J. regia* sites are well drained to moderately well drained; excessively drained or poorly drained sites are unsuitable.

Table 6. Factor rating of land characteristics and suitability class for *Salix alba* L.

L.M.U	Soil physical and chemical characteristics								Final index	Class
	Drainage	Depth	pH	EC	$CaCO_3$	O.M	Texture	C.F		
Cs.1	40	80	100	100	100	100	30	60	18	N
Cs.2	80	100	100	100	100	100	80	100	76	S2
Cs.3	30	60	100	100	100	100	10	80	9	N
Ay.1	100	100	100	100	80	100	100	100	87	S1
Ay.2	100	100	100	100	80	100	100	100	87	S1
Ka.1	100	100	100	100	70	100	100	100	81	S1
Ka.2	100	100	100	100	100	100	100	100	100	S1
Cy.1	80	100	100	100	100	100	100	100	87	S1
Cy.2	100	100	100	100	100	100	100	100	100	S1
Cy.3	70	100	100	100	100	100	100	70	65	S2
Ki.1	100	100	100	100	100	100	100	100	100	S1
Ki.2	90	100	100	80	100	100	80	100	71	S2
Ki.3	100	100	100	100	100	100	100	100	100	S1
Ki.4	100	100	100	80	100	100	100	100	87	S1
Ki.5	100	100	100	80	100	100	100	100	87	S1
Ac.1	100	100	100	100	80	100	70	90	66	S2
Ac.2	80	100	100	100	100	100	100	90	82	S1
Ac.3	100	100	100	100	100	100	70	90	75	S2
Ac.4	100	100	100	100	80	100	70	90	66	S2
Ep.1	100	100	100	100	100	100	70	100	81	S1
Ep.2	100	100	100	100	100	100	100	100	100	S1
Ep.3	100	100	100	100	100	100	80	100	87	S1
Kt.1	100	100	100	100	100	100	80	100	87	S1
Kt.2	100	100	100	80	100	100	100	100	87	S1
Kt.3	100	100	100	100	100	100	100	100	100	S1
Kt.4	100	100	100	70	100	100	100	100	81	S1
Kt.5	60	100	100	100	100	100	50	100	49	S3
Kt.6	100	100	100	100	100	100	100	100	100	S1
Kt.7	100	100	100	80	100	100	100	100	87	S1

LMU: Land Mapping Unit, CF: Coarse Fragments, OM: Organic Matter, EC: Electrical Conductivity.

A soil's texture is determined by the amounts of sand, silt and clay particles it contains in the study area. A soil with moderately fine texture (more silt than clay or sand), such as a silt loam located on Çaylı soil series, will generally have sufficient amounts of nutrients, yet will be reasonably well drained.

Sandy soils found on Costal soil series are often low in nutrients and are excessively drained; heavy textured soils, such as clays, may limit water movement and rooting of this species. In addition, this tree requires low content of carbonates and soil pH 6.5- 7.2. It is almost not suitable in 23% of the study area due to high salt concentration, poor or excessive drainage, whereas, 63% of the total area is highly suitable for this species (Figure 3). From a social point of view, the social forestry is directed primarily at the need of the local community. The social forestry relate to these elements: Fuel wood, domestic timber, fruits, roots, medicines, grazing, hunting etc. (FAO, 1984).

For this aim, three species, *Populus* sp., *S. alba*, and *R. pseudoacacia,* were considered because they are the original and common grown species of this area. *Populus* sp., a rapid growth species, is preferred as fuel wood and domestic timber. The general characteristics of the investigated soil which matches the requirements of this tree are well drained, high in calcium, low salt content, loamy soils.

In addition to land and soil requirement of *Populus* sp., water table level should have 1.0 -1.5 m depth and clay content of less than 40%. It slightly pre-fers acid and medium alkaline soil reaction. Moist in wet sites, depressions, floodplains along major rivers places are

Table 7. Factor rating of land characteristics and suitability class for *Robinia pseudo-acacia* L.

L.M.U	Soil physical and chemical characteristics								Final index	Class
	Drainage	Depth	pH	EC	$CaCO_3$	O.M	Texture	C.F		
Cs.1	100	70	100	100	100	80	100	100	70	S2
Cs.2	100	100	100	100	100	100	100	100	100	S1
Cs.3	50	50	100	100	100	80	100	90	36	S3
Ay.1	70	100	100	100	70	100	60	100	47	S3
Ay.2	100	100	100	100	100	100	100	100	100	S1
Ka.1	100	100	100	100	100	100	100	100	100	S1
Ka.2	100	100	100	80	100	100	100	100	87	S1
Cy.1	80	100	100	100	100	100	70	100	70	S2
Cy.2	100	100	100	100	100	100	100	100	100	S1
Cy.3	70	100	100	100	100	100	100	100	81	S1
Ki.1	90	100	100	100	80	100	90	100	76	S2
Ki.2	100	100	100	60	100	100	100	70	59	S3
Ki.3	100	100	80	50	100	100	60	100	42	S3
Ki.4	50	100	80	80	90	100	80	100	41	S3
Ki.5	100	100	60	30	100	100	80	70	25	N
Ac.1	80	100	100	100	80	100	100	100	76	S2
Ac.2	100	100	100	100	80	100	100	100	87	S1
Ac.3	100	100	100	100	80	100	100	100	87	S1
Ac.4	70	100	100	100	80	100	80	100	61	S2
Ep.1	100	100	100	100	100	100	100	100	100	S1
Ep.2	60	100	100	100	100	100	60	100	54	S3
Ep.3	70	100	100	100	100	100	60	100	59	S3
Kt.1	70	100	100	100	100	100	100	100	81	S1
Kt.2	100	100	100	100	100	100	100	100	100	S1
Kt.3	100	100	100	100	100	100	100	100	100	S1
Kt.4	100	100	100	10	100	80	100	80	21	N
Kt.5	100	100	100	100	100	100	100	100	100	S1
Kt.6	50	100	100	50	100	80	100	100	38	S3
Kt.7	100	100	100	30	100	100	80	100	43	S3

LMU: Land Mapping Unit, CF: Coarse Fragments, OM: Organic Matter, EC: Electrical Conductivity.

suitable for this species. Results show that this tree is almost suitable in 83% of the study area (Figure 4). It is highly suitable in 64% ofthe lands. Non suitable area is only 16% of the study area including limiting factors such as high salt concentration, high sand content and very close water table level to soil surface. *S. alba* belongs to the rapid growing tree species grown to stabilize hillsides, coasts, sand dunes and sands against wild and water erosion. *S. alba* is demanding in terms of soil characteristics. In general, soils should have light texture, low calcium carbonate, high nutrient content and moist and moderate acid and alkaline condition. It has a dominating role in plant community areas with raised soil moisture, especially along rivers and lakes, in humid, overgrown meadows, and often in ecosystems transformed by humans.

For the *S. alba,* 84.2% of the study area was classified as highly and moderately suitable (S1 and S2) and are mostly located in all series. Besides, 14.1% was classified as non suitable (N) and are generally common on costal soil series and marsh-swamp areas. Only 1.4% of the study area is found marginally suitable (S3) (Figure

Table 8. Factor rating of land characteristics and suitability class for *Fraxinus excelsior* L.

L.M.U	Soil physical and chemical characteristics								Final index	Class
	Drainage	Depth	pH	EC	$CaCO_3$	O.M	Texture	C.F		
Cs.1	70	50	100	100	100	60	80	90	32	S3
Cs.2	100	100	100	100	100	100	100	100	100	S1
Cs.3	30	50	100	100	100	60	50	70	12	N
Ay.1	70	100	100	100	100	100	90	100	75	S2
Ay.2	100	100	100	100	80	100	100	100	87	S1
Ka.1	100	100	100	100	100	100	100	100	100	S1
Ka.2	100	100	100	70	100	100	100	100	81	S1
Cy.1	80	100	100	100	100	100	80	100	76	S3
Cy.2	100	100	100	100	100	100	100	100	100	S1
Cy.3	90	100	100	100	100	100	100	100	94	S1
Ki.1	100	100	100	100	100	100	100	100	100	S1
Ki.2	80	100	100	50	100	100	60	100	42	S3
Ki.3	80	100	100	80	100	100	100	80	66	S2
Ki.4	100	100	100	100	100	100	100	100	100	S1
Ki.5	50	80	100	30	100	80	50	100	16	N
Ac.1	100	100	90	100	80	100	90	100	76	S2
Ac.2	100	100	90	70	100	100	90	100	71	S2
Ac.3	100	100	90	100	100	100	100	100	94	S1
Ac.4	100	100	90	100	80	100	80	100	71	S2
Ep.1	100	100	100	100	100	100	100	100	100	S1
Ep.2	80	100	100	100	100	100	80	100	76	S2
Ep.3	100	100	100	100	100	100	100	100	100	S1
Kt.1	100	100	100	100	100	100	100	100	100	S1
Kt.2	100	100	100	100	100	80	100	100	87	S1
Kt.3	100	100	100	100	100	100	100	100	100	S1
Kt.4	100	100	30	100	100	100	100	100	50	S3
Kt.5	100	100	100	100	100	100	100	100	100	S1
Kt.6	100	100	100	100	100	80	100	90	82	S1
Kt.7	100	100	10	100	100	100	100	100	28	N

LMU: Land Mapping Unit, CF: Coarse Fragments, OM: Organic Matter, EC: Electrical Conductivity.

4). Establishment of *R. pseudoacacia* that produces timber of good quality is possible only on sites with adequate moisture and well-aerated and preferably light soils, deep, rich in nutrients and organic matter. *R. pseudoacacia* have no tolerance for high calcium carbonate and high salt concentration and are generally utilized for the production of fuel wood, fodder, poles and props, as well as for honey production, soil protection and environmental improvement. The most important *R. pseudoacacia* growing regions are located in alluvial, river bank zones and depressions with water present below the surface and drier areas with a high water table. For *R. pseudoacacia,* a good proportion (53.1%) of the study area is highly suitable (S1) and 37.6% is classified as moderately and marginally suitable (S2 and S3). Only a few lands are found to be almost unsuitable (N, 9.3%).

Conclusion

This effort was based on the ecological and economic-social expectations for that time, which dictated that *Pinus pinaster* Ait., *Pinus radiata* D. Don, *Pinus pinea* L., *Populus* L., *Salix alba* L., *Robinia pseudoacacia* L., *Fraxinus excelsior* L., and *Juglans regia* L. would be logical species for replanting in the study area. This is

Table 9. Factor rating of land characteristics and suitability class for *Juglans regia* L.

L.M.U	Soil Physical and Chemical Characteristics								Final index	Class
	Drainage	Depth	pH	EC	$CaCO_3$	O.M	Texture	C.F		
Cs.1	40	80	100	100	100	80	50	80	25	N
Cs.2	100	100	100	100	100	100	100	100	100	S1
Cs.3	30	10	100	100	100	70	50	50	5	N
Ay.1	80	100	100	100	100	100	90	100	82	S1
Ay.2	100	100	100	100	80	100	100	100	87	S1
Ka.1	100	100	100	100	80	100	100	100	87	S1
Ka.2	80	100	100	100	100	100	70	100	70	S2
Cy.1	90	100	100	100	100	100	90	100	88	S1
Cy.2	80	100	100	100	100	100	90	100	82	S1
Cy.3	100	100	100	100	100	100	90	100	94	S1
Ki.1	80	100	100	100	80	100	100	90	71	S2
Ki.2	70	100	80	50	100	100	100	90	43	S3
Ki.3	100	100	80	30	100	100	100	100	43	S3
Ki.4	60	100	100	30	100	100	100	100	37	S3
Ki.5	100	100	30	10	100	100	50	50	6	N
Ac.1	100	100	100	100	80	100	100	100	87	S1
Ac.2	80	100	100	100	100	100	90	100	82	S1
Ac.3	90	100	100	100	100	100	80	100	82	S1
Ac.4	70	100	100	100	80	100	80	100	61	S2
Ep.1	100	100	100	100	100	100	100	100	100	S1
Ep.2	100	100	100	100	100	100	100	100	100	S1
Ep.3	70	100	100	100	100	100	90	100	75	S2
Kt.1	100	100	100	100	100	100	100	100	100	S1
Kt.2	80	100	100	100	100	100	90	80	71	S2
Kt.3	100	100	100	100	100	100	100	100	100	S1
Kt.4	60	100	50	20	100	100	100	80	17	N
Kt.5	100	100	100	100	100	100	70	80	70	S2
Kt.6	100	100	100	100	100	100	100	100	100	S1
Kt.7	80	100	100	10	100	100	70	100	20	N

LMU: Land Mapping Unit, CF: Coarse Fragments, OM: Organic Matter, EC: Electrical Conductivity

why the main issue of land suitability classification is considered to be an aid to decision-making in terms of providing economical and social support to strengthen forestry potential to combat land degradation which are the most important constraints in the study area.

It is also necessary to use the modern methods of surveying and analyzing tools. That is why GIS with its capability of data collection and analysis is now considered as efficient and effective tools for land evaluation of forest plantation area. The capability of GIS to analyze information across space and time would help in managing such dynamic systems (Dengiz, 2006). The study shows that the efficiency of this tool to analyze the information on evaluation system in various domains in an integrated manner helps to understand the system. It is also very easy to update data involved in GIS database with more accuracy and reliability.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the scientific

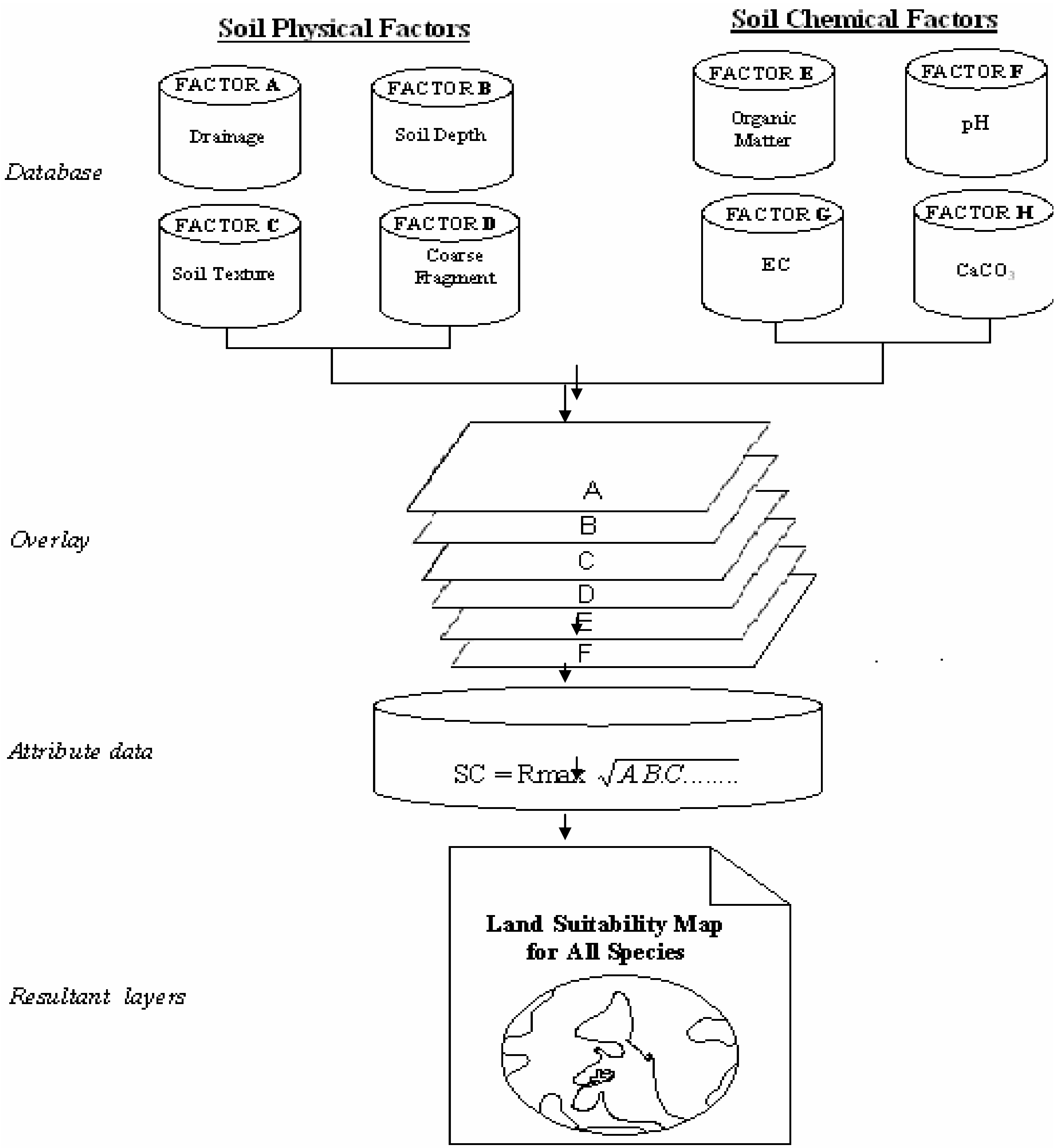

Figure 2. Schematic chart of GIS application for eight different species suitability maps.

research grant (TUBITAK 107-O-443) of the Scientific and Technological Research Council of Turkey, especially during the soil survey and mapping study of this research.

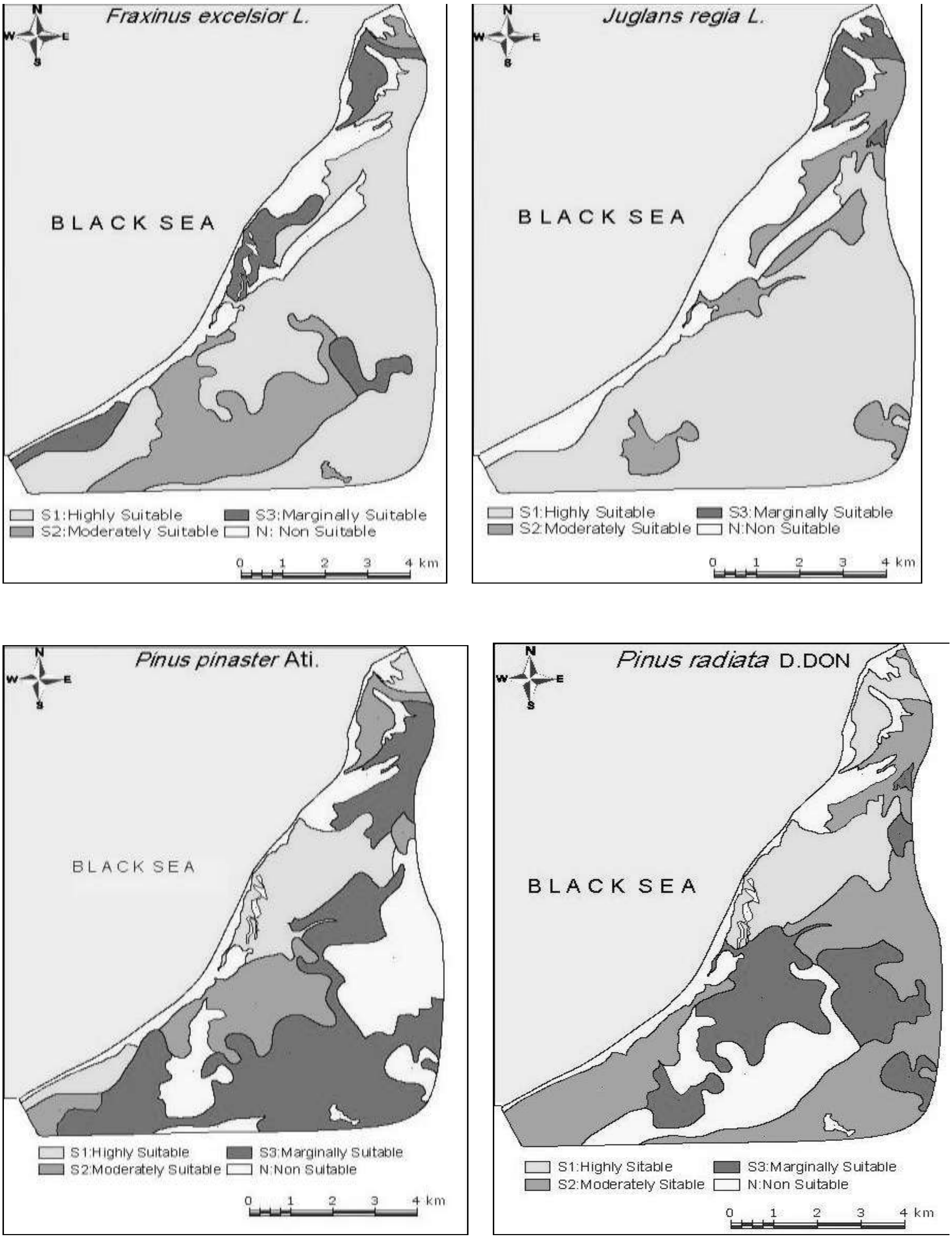

Figure 3. Land suitability maps for *Fraxinus excelsior* L., *Juglans regia* L., *Pinus pinaster* Ait, *Pinus pinea* L.

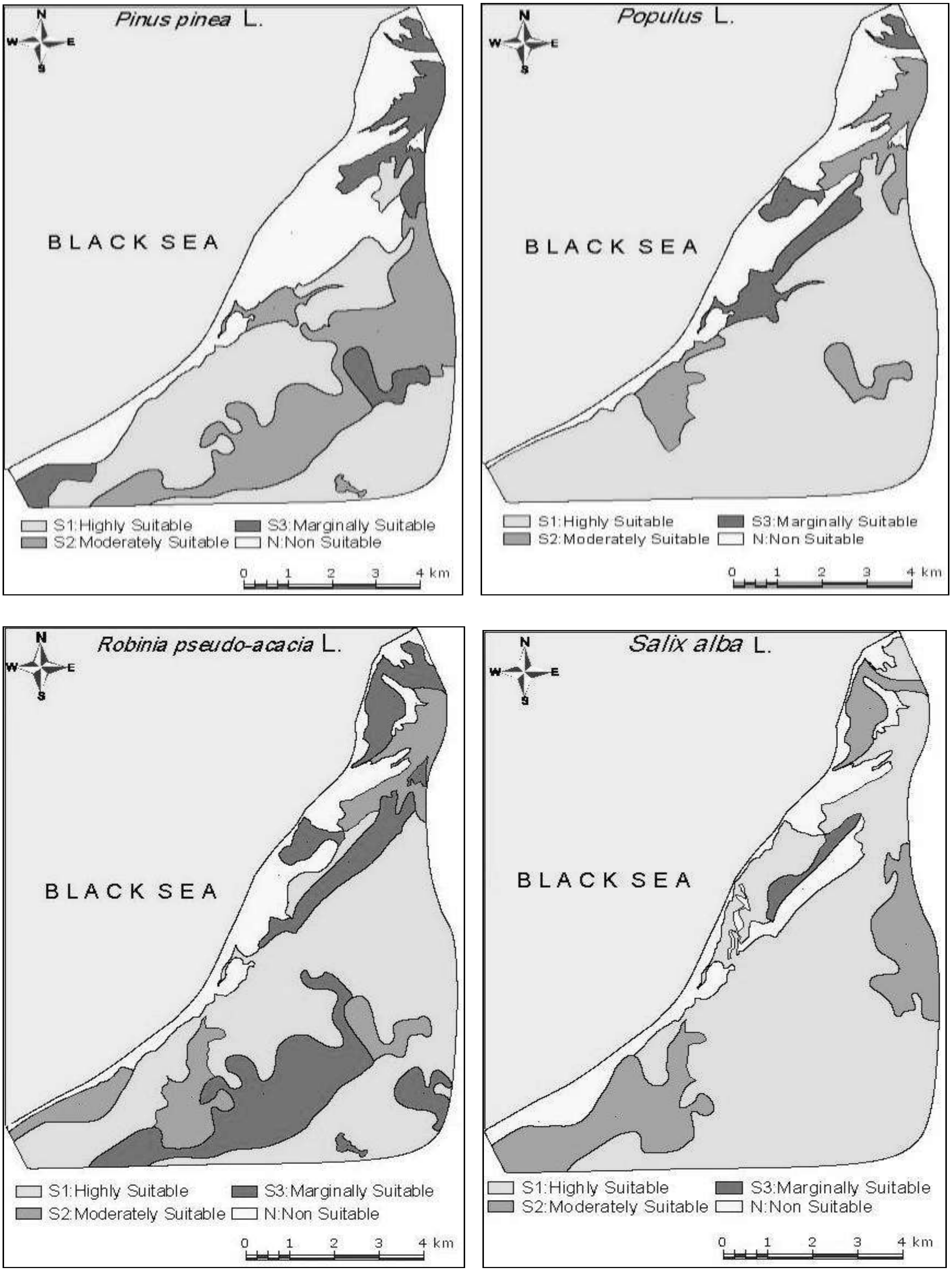

Figure 4. Land suitability maps for *Pinus radiata* D. DON, *Populus* L., *Robinia pseudo-acacia* L., *Salix alba* L.

REFERENCES

Anşin R, Özkan ZC (1997). Tohumlu bitkiler (Spermatophyta), odunsu taksonlar. Karadeniz Teknik Üniversitesi, Orman Fakültesi, Yayın No: 167, Trabzon (In Turkish).

Anonymous (1994). Türkiye'de kavakçılık. T.C. Orman Bakanlığı, Kavak ve Hızlı Gelişen Tür Orman Ağaçları Araştırma Müdürlüğü (In Turkish).

Blaschke GW, Heitz R, Blaschke M, Amer C (2008). Growth and nutrition of young European ash (Fraxinus excelsior L.) and sycamore maple (*Acer pseudoplatanus* L.) on sites with diVerent nutrient and water statuses, Eur. J. Forest. Res., 127: 465-479.

Dayawansa NDK, Ekanayake GK (2003). Land suitability identification for a production forest through GIS Techniques. Forestry and Biodiversity, Map India Conference.

Dengiz O **(**2006). Comparison of Different Irrigation Methods Based on the Parametric Evaluation Approach, Turk. J. Agric., 30(1): 21-29.

Evrendilek F, Doygun H (2000). Assessing major ecosystem types and the challenge of sustainability in Turkey. Env. Manage., 26(5): 479-489.

FAO (1976). A Framework for Land Evaluation, Institute for Land Reclamation and improvement / ILRI. Publication 22, Wageningen, The Nederland's, p. 87.

FAO (1983). Freshwater aquaculture development in China. Report of the FAO/UNDP study tour organized for French- speaking African countries, 22 April- 20 May 1980. FAO Fish. Tech., pp. 125-215.

FAO (1985). Guidelines: land evaluation for irrigated agriculture Rome, Italy. Soils Bulletin, p. 55.

FAO (1984). Land evaluation for forestry. Food and Agriculture Organization of the United Nations. Forestry Rome, Italy. pp. 48-123.

FAO (1981). Food Balance Sheets, average. Food and Agriculture Organization of the United Nations. Rome, Italy.

Ikawa H (1992). Soil Taxonomy and Land Evaluation for Forest Establishment, USDA Forest Service Gen.tech., Rep. PSW-129.

Kantarci MD (2005). Ağaçlı (İstanbul) açık maden ocağı artıklarının ıslahı ve ağaçlandırılması çalışmalarında elde edilen sonuçlar. Madencilik ve Çevre Sempozyumu, Bildiriler Kitabı, Mayıs, Ankara (In Turkish). pp. 5-6.

Kiliç Ş, Evrendilek F, Şenol S, Çelik İ (2005). Developing a suitability index for land uses and agricultural land covers: A case study in Turkey, Environ. Monitoring Assessment, 102: 323-335.

Millington DL (1984). Reconnaissance scale soil erosion mapping using a simple GIS in the humid tropics, In: W. Siderus (ed.), Land Evaluation for Land-Use Planning and Conservation in Sloping Areas. International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands. pp. 64-81.

McBratney AB, Odeh IOA, Bishop TFA, Dunbar MS, Shatar TM (2000). An overview of pedometric techniques for use in soil survey. Geoderma, 97: 293-327.

Olarieta JR, Besga G, Rodriguez R, Aizpurua A, Uson A (2006). Land evaluation for forestry: a study of the land requirements for growing Pinus radiata D. Don in the Basque Country, northern Spain. Soil Use and Management. 22: 238-244.

Parker D, Bockheim J, Meyer D (1992). Walnut Tips-Soil and Site Selection, Forest Facts, Agricultural and Life Sci, 58: 1-2.

Pinto MC, Henry CG, Guibal F, Roux M (2004). Dendrometry and morphometry of Pinus pinea L. in Lower Provence (France): adaptability and variability of provenances. Forest. Ecol. Manage., 149: 319-333.

Pini R, Paris P, Benetti A, Guidi GV, Pisanelli A (1999). Soil physical characteristics and understory management in a walnut (Juglans regia L.) plantation in central Italy. Agroforest. Syst., 46: 95-105.

Redei K., Bujtas OZ, Veperdi I (2008). Black Locust (Robinia pseudoacacia L.*)* Improvement in Hungary: a Review, Acta Silv. Lign. Hung., 4: 127-132.

Rietveld WJ (1982). The Significance of allelopathy in black walnut cultural systems, black walnut for the future. USDA Forest Service General Technical Report, 74: 73-86.

Riquier J, Bramao DL, Cornet JP (1970). A new system of soil appraisal in terms of actual and potential productivity. FAO Soil Resources, Development and Conservation Service, Land and Water Development Division. FAO, Rome, p. 38.

Romanya J, Vallejo VR (2004). Productivity of Pinus radiata plantations in Spain in response to climate and soil, Forest Ecol. Manag., 195: 177-189.

Rossiter DG (1996). A theoretical framework for land evaluation (with discussion), Geoderma, 72: 165-202.

Saatçioğlu F (1976). Silvikültür I. Silvikültürün Biyolojik Esasları ve Prensipleri. İstanbul Üniversitesi, Orman Fakültesi (In Turkish), Yayın. p. 2187.

Sarıbas M (2008). Dendroloji, Gymnospermea In Turkish. 101(3): 69-70.

Sever H, Makineci E (2008). Ağaçlı-İstanbul maden sahalarında sahil camı (Pinus Pinaster Aiton.) ağaçlandırmalarında bazı ölü örtü ve toprak özellikleri. Süleyman Demirel Üniversitesi Orman Fakültesi Dergisi (In Turkish), 2: 136-146.

Soil Taxonomy (1999). A Basic of Soil Classification for Making and Interpreting Soil Survey. Soil Survey Staff. U.S.D.A, Handbook, Washington, D.C. p. 436.

Todhunter MNWF (1984). Beineeke, Effect of Anthracnose on Growth of Grafted Black Walnut. Plant Disease, 68: 203-204.

Toplu F, Küçükosmanoğlu F, Karakaş A, Selek F (2002). Korsika orjinli sahil camı (Pinus Pinaster Ait.) orjin denemesinde (Balıkesir-Ilıca) kar zararları. Kavak ve Hızlı Gelişen Yabancı Tür Orman Ağaçları Araştırma Enstitüsü (In Turkish)., Yıllık bülten, Yayın, pp. 21-184.

Tunçtaner K, Tulukçu M, Toplu F (1985). Türkiye'de endüstriyel ağaçlandırmalarda kullanılabilecek sahilçamı (Pinus pinaster Ait.) orjinlerinin seçimi üzerine araştırmalar. Kavak ve Hızlı Gelişen Yabancı Tür Orman Ağaçları Araştırma Enstitüsü, Yıllık bülten (In Turkish). p. 21.

Turvey ND, Rudra AB, Turner J (1986). Characteristics of Soil and Productivity of Pinus Radiata (D. Don) In New South Wales. I. Relative importance of soil physical and chemical parameters. Aust. J. Soil. Res., 24: 95-102.

UN (1986). World Population Prospects. Estimates and Projections as Assessed in (1984). Population Studies. International Economic and Social Affairs, Statistical Office. United Nations, New York. p. 98.

Ürgenç S (1972). Hızlı gelişen bazı ekzotik (yabancı) iğne yapraklı ağaç türlerinin ithali ve yetiştirilmesi üzerine araştırmalar. Istanbul Universitesi. Orman Fakültesi (In Turkish). Yayın, pp. 175-188.

Van Diepen CA, Van Keulen H, Wolf J, Berkhout JAA (1991). Land Evaluation: From Intuition to Quantification. In: Advances In Soil Science, ed. BA Stewart, Springer, New York, pp. 139-204.

Yaltırık F, Efe A (2000). Dendroloji (Gymnospermae-Angiospermae). İstanbul Üniversitesi, Orman Fakültesi, (In Turkish). Yayın No: 4265.

Yüksel M, Dengiz O, Göl C (2002). Cankırı-Kenbag Orman Fidanlıgı Topraklarının Fiziksel, Kimyasal Özellikleri ve Sınıflandırması. Süleyman Demirel Üniversitesi Orman Fakültesi Dergisi (In Turkish). Seri: A, Sayı, 2: 11-26.